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APPLICATION NOTE

Generalized-Geometry Gamma-Ray Holdup Assay

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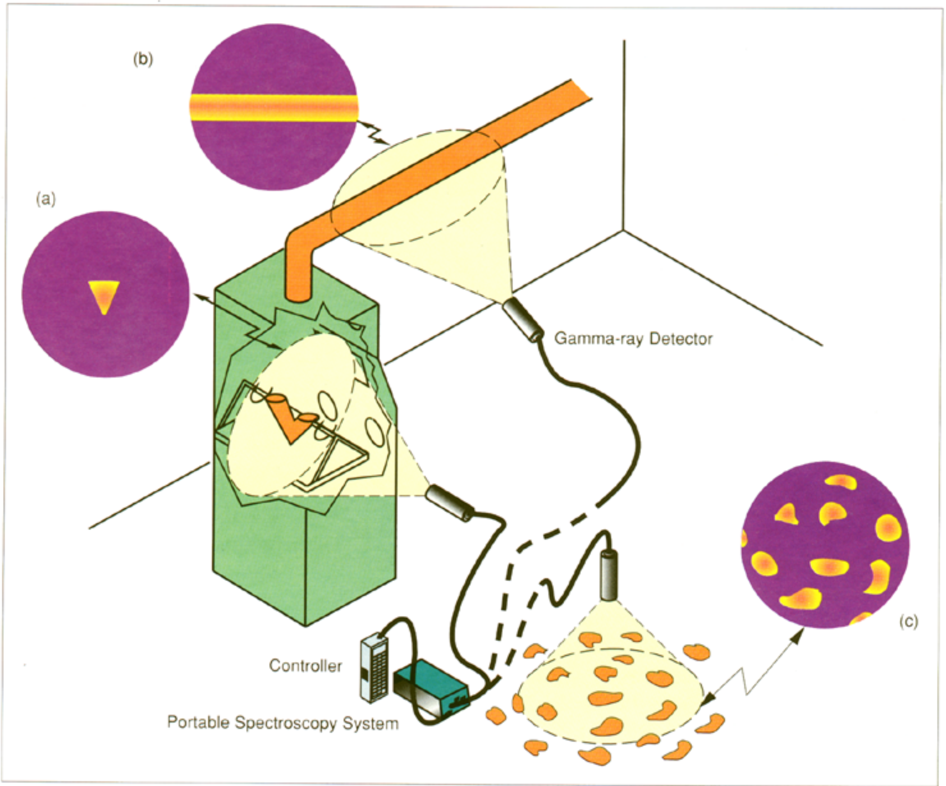

Figure 1. The generalized-geometry method is the key to plantwide quantitative assays of holdup. A cylindrically collimated gamma-ray detector connected to a portable spectroscopy system automated by a palm-size controller measures nuclear material (orange) in three generalized geometries: (a) a small deposit centered in a relatively large circular field of view (FOV); (b) a narrow, uniform deposit centered in a relatively wide FOV; and (c) a uniform deposit that fills a circular FOV.

Holdup is deposited in diverse, often hard-to-reach, locations throughout nuclear material processing plants. Nevertheless, accurate plant-wide assays of special nuclear material (SNM) holdup must be performed rapidly and often. Quantitative assay of SNM holdup using gamma-ray spectroscopy requires a simple, compact, reliable, and portable system that must ensure the high quality of gamma-ray spectra acquired rapidly. A way to simplify and speed up the process is to reduce the number of measurement geometries from many to three: point, line, and area. By examining the plant and judiciously defining the measurement geometry at each location, one of only three distinct calibrations can be used to assay holdup with acceptable accuracy at each of hundreds of different locations. Barcoding the locations, automating data readout, and encoding the distance of the detector from the deposit greatly simplifies the measurement process. This generalized geometry holdup (GGH) methodology allows the rapid and accurate quantitative analysis of holdup in miles of ductwork, hundreds of valves and pipes, and dozens of pieces of process equipment.

PLANTWIDE HOLDUP ASSAY SYSTEM

A generalized calibration and assay methodology that reduces thousands of unique measurement geometries to three simple categories is more than a general method. The system relies on hardware and software to make assays possible. The hardware allows a single user to make the measurements under physically demanding circumstances. It consists of a portable spectroscopy system that acquires gamma-ray spectra from deposits in the plant; a hand-held programmable controller that sets up hardware, executes all hardware functions, and stores raw and reduced spectral data, quality-assurance reference values, and setup values for the portable spectroscopy hardware; and a compact, shielded, collimated gamma-ray detector. The intelligence programmed in the controller sets up and operates the portable hardware for data acquisition, assures control and quality of data, links measurement functions, and reduces holdup measurement data. Subsequently, analysis and management of raw or reduced data is automated by a PC data base, spreadsheet, or other software, and holdup is quantified (using the generalized prescription), tracked, reported, and archived as required by the facility and the regulators. Specific components of a complete system are

Generalized calibration and assay methodology—GGH Assay Method.[1-4]

Hardware for portable GGH measurements—Portable gamma-ray spectroscopy system such as the Davidson Corp. Portable Multichannel Analyzer (PMCA) or the smaller and more powerful Los Alamos miniature modular multichannel analyzer (M^3CA)[5,6]; Intermec (bar-code-reader-equipped) palm-sized control unit; and Bicron compact, collimated, shielded NaI(Tl) detectors.

Intelligence and automation of the GGH system—Spectroscopy system firmware for external ASCII control of setup and function of the portable gamma-ray spectroscopy system; HMSII software written for the controller and any 286 or higher PC.

GGH ASSAY METHOD

Gamma-ray measurements for quantitative analysis of nuclear material holdup are complex, in that each measurement can represent a unique geometry that requires its own calibration. Because holdup determinations involve analysis of hundreds to thousands of spectra per measurement period, the calibration and measurement efforts must be simple and the analysis must be applicable to the unique geometry of each measurement. This is accomplished by adjusting holdup measurement geometries in the FOV of a cylindrically collimated gamma-ray detector so that each holdup deposit geometry can be generalized to one of three mathematically simple categories: a point, line, or area deposit. The calibration has a unique dependence on r, the distance between the source and the detector surface, and a unique geometric normalization for a given collimated detector for each of the three generalized geometries. Descriptions of the geometric models, analytical formulas, and calibration and measurement procedures are given elsewhere.[1-4]

HARDWARE FOR PORTABLE GGH MEASUREMENTS

The PMCA or M^3CA coupled with a gamma-ray detector and a programmable controller is a complete, portable gamma-ray spectroscopy system. Figure 2 shows a technician at the Oak Ridge Y-12 Plant using such a portable gamma-ray spectroscopy system for holdup measurements. Figure 3 shows this hardware in more detail.

For field operation, the requirements of the controller are the serial interface and programmability. The PMCA or M^3CA hardware setup is digitally automated by the controller, a PC or other programmable unit such as the Intermec 9440. Quality assurance and control (QA/QC) software (running in the controller) coupled to internal (PMCA- or M^3CA-firmware) analysis of reference gamma-ray peaks assures spectrum and assay quality during portable measurements, simplifying the requirements for the basic hardware unit by eliminating the need for visual examination of gamma-ray spectra during the measurements of holdup.

The Intermec 9440, manufactured by Intermec Corp., is a programmable, digital, control-and-data-storage unit that is equipped with a bar-code reader. The reliability, versatility, and compact but rugged design of this instrument have been demonstrated in portable measurement applications auto-

Oak Ridge Y-12 Photo: 308686

Figure 2. A technician at the Y-12 Plant measures holdup with the portable equipment shown in Fig. 3. The detector views a portion of the overhead duct marked by a barcoded label directly above the hand-held detector.

LANL Photo: RN 93 111019

Figure 3. The portable equipment for automated, reliable, single-user, plantwide measurements of holdup. Shown are the M^3CA (center), Intermec control unit (left) , and Bicron detector (right).

mated and managed by this programmable bar-code reader/ data logger.[7,8]

The compact, collimated, shielded NaI(Tl) detector, manufactured by Bicron Corp., is a 1-in.-diameter by 0.5- or 2-in.-thick NaI(Tl) crystal. The mechanical and electronic designs of this compact detector were developed at Los Alamos for measurements of holdup. It has been available commercially since 1991. The 1M.5/1LP-X model is pictured at the right in Fig. 3. Information on the design and development of this detector is available elsewhere.[9,10]

INTELLIGENCE AND AUTOMATION OF THE PORTABLE GGH SYSTEM

The software that runs in the external programmable controller sets up the hardware and executes the generic multichannel analyzer functions. Serial communications between the controller unit and PMCA or M^3CA firmware for setup and execution are in ASCII. The serial port is also used to transfer spectral data (spectra, region-of-interest integrals, net peak areas, peak channels, or centroids) and hardware settings and statuses. Digital gain-drift detection/compensation for spectrum QA/QC is performed by the external controller software in communication with the PMCA or M^3CA firmware.[11]

The HMSII (Holdup Measurement System II) software is a modular package, designed to run on any 286 (or higher) PC.[12] The HMSII software automates the otherwise tedious GGH calibration, sets up the PMCA or M^3CA controller unit to automate holdup measurements in the plant, receives files of reduced holdup measurement data from the controller, and performs the GGH analysis of this data. The GGH analysis is coupled to a comprehensive data base that contains specifications on the process equipment at the individual bar-coded measurement locations and on equipment units as a whole. This information is used to correct for equipment effects, such as attenuation and finite-source effects, and to obtain holdup at individual locations within a piece of equipment or process line as well as the total for the equipment unit or process line. One module of HMSII that runs in the Intermec controller sets up and controls the PMCA or M^3CA for holdup measurements, logs in the bar-coded measurement locations, and stores the reduced holdup measurement data. The automation provided by the controller hardware and HMSII software module enables reliable operation by an inexperienced single user, eliminates transcription errors, enforces adherence to prescribed measurement control/quality assurance standards, and reduces the time required to perform reliable holdup measurements by tenfold or more compared to manual operations with equivalent instrumentation.

PERFORMANCE OF THE GAMMA-RAY GGH METHOD WITH HMSII

A field evaluation of the performance of the portable gamma-ray GGH methodology automated by the HMSII software is in progress. The system is in use at the Martin Marietta Energy Systems Oak Ridge Y-12 Plant for determination of uranium holdup in the facility's process equipment. In this field evaluation, the gamma-ray GGH assay results will be compared with reference values obtained following a cleanout of the process equipment.

Additional Sources of Information

1. N. Ensslin and H. A. Smith, Jr., "Attribute and Semiquantitative Measurements," in D. Reilly, N. Ensslin, H. A. Smith, Jr., and S. Kreiner, Eds., *Passive Nondestructive Assay of Nuclear Materials* (Washington D.C., Government Printing Office, 1991) NUREG CR-5550, pp. 589–615.

2. T. R. Wenz, P. A. Russo, M. C. Miller, and H. O. Menlove, "Portable Gamma-Ray Holdup and Attributes Measurements of High- and Variable-Burnup Plutonium," in *Proceedings of 4th International Conference on Facility Operations - Safeguards Interface* (American Nuclear Society, Inc., La Grange Park, Illinois, 1992), ANS Order No. 700168, pp. 226–236.

3. P. A. Russo, R. Siebelist, J. A. Painter, and J. E. Gilmer, "High-Resolution Gamma-Ray Methods for Determination of Solid Plutonium Holdup in High-Throughput Bulk-Processing Equipment," Los Alamos National Laboratory report LA-11729-MS (1990).

4. P. A. Russo, J. K. Sprinkle, Jr., and T. H. Elmont, "Holdup Measurements of the Rocky Flats Plant 371 Precipitator Canyons," Los Alamos National Laboratory report LA-10967-MS (1987).

5. J. K. Halbig, S. F. Klosterbuer, P. A. Russo, J. K. Sprinkle, Jr., and S. E. Smith, "Advances in Gamma-Ray Field Instrumentation at Los Alamos," Los Alamos National Laboratory document LA-UR-93-2784 (1994).

6. J. K. Sprinkle, Jr., J. K. Halbig, S. F. Klosterbuer, P. A. Russo, and S. E. Smith, "A Miniature, Modular MCA for Gamma-Ray Spectroscopy," Los Alamos National Laboratory document LA-UR-93-1727 (1993).

7. S. E. Smith, "An Emergency Inventory System at the Oak Ridge Y-12 Plant," *Proceedings, 28th Annual Meeting of INMM*, Vol. 16 (Institute of Nuclear Materials Management, Northbrook, Illinois, 1987).

8. S. E. Smith, J. S. Gibson, J. K. Halbig, S. F. Klosterbuer, P. A. Russo, and J. K. Sprinkle, Jr., "The Holdup Measurement System II (HMSII)," *Proceedings, 33rd Annual Meeting of INMM*, Vol. 22 (Institute for Nuclear Materials Management, Northbrook, Illinois, 1993).

9. P. A. Russo, M. M. Stephens, and S. C. Bourret, "Compact NaI(Tl) Detectors," in "Safeguards and Security Progress Report, January-September 1989," D. B. Smith and G. R. Jaramillo, Comps., Los Alamos National Laboratory report LA-11914-PR (1990), pp. 20–22.

10. P. A. Russo, C. W. Bjork, M. M. Stephens, and D. A. Close, "Elimination of Gain Instability in Compact NaI(Tl) Detectors," in "Safeguards and Security Progress Report, January-September 1990," D. B. Smith and G. R. Jaramillo, Comps., Los Alamos National Laboratory report LA-12095-PR (1991), pp. 18–19.

11. P. A. Russo, T. R. Wenz, and J. A. Painter, "Experimental Evaluation of Software-Driven Digital Gain-Drift Compensation in Scintillator Gamma-Ray Spectroscopy," Los Alamos National Laboratory report LA-12390-MS (1992).

12. S. E. Smith, "Holdup Measurement System II (HMSII, version 1.0)," Martin Marietta Energy Systems Y-12 Plant report Y/MA-37-7210 (1993).

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